CRITICAL THINKING IN ELECTRICITY AND MAGNETISM: AN ASSESSMENT TOOL FOR SECONDARY SCHOOL STUDENTS

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Critical thinking (CT) is one of the most desirable objectives of education. However, many questions regarding introducing CT in education remain unanswered. What is CT? How can CT be assessed? Is CT domain specific or domain general?... This work focuses on the assessment of CT, and for the purposes of this study we regard CT as domain specific. However, most CT-tests are domain general. Therefore, confronted with educational goals that focus on CT on the one hand and the lack of validated tests to test domain-specific CT on the other hand, this study aims at constructing and validating a domain-specific test for physics; more specifically for electricity and magnetism (E&M). The test is aimed at secondary school students that have received instruction on E&M. The developed test shows, for the convenience sample taken in Flanders (Belgium), that students perform very poorly on the test. This result suggests that students in Flanders are not adequately prepared to think critically within the domain of physics.

Keywords: Critical thinking, physics, secondary education

INTRODUCTION

Critical thinking (CT) is one of the most desirable objectives of most, if not all, secondary education curricula. However, many questions remain unanswered when teachers try to address this end goal. What is CT? How can CT be assessed? How can CT be stimulated in the classroom? In this work we try to, in part, address the second question. Of course in order to do this the first question must be answered. Literature has provided many definitions for CT (Paul, & Elder, 2001; Mcpeck, 2016; Ennis, 2011; Facione, 1990; Robinson, 2011; Davies, 2013; Halpern, 2002). A comparison of these definitions reveals disagreement on two aspects of CT. Is CT just a skill or does it comprise a disposition? And, is CT domain-specific or domain-general? I.e. can someone who learned to think critically in one domain think critically in all other domains? Are CT skills, and/or dispositions, transferable (Lai, 2011)? While many authors strongly stress the importance of domain-specific knowledge for CT and hence stress the domain-specificity of CT, CT-tests at this moment are mainly domain-general. There is a need for domain-specific tests to advance the field.

Confronted with educational goals that focus on CT on the one hand and the lack of validated tests to test domain-specific CT on the other hand, this study aims at constructing and validating a domain-specific test for physics; more specifically for electricity and magnetism (E&M). The test is aimed at secondary school students that have received instruction on E&M.

METHOD

The development of the test follows design guidelines (Adams, & Wieman, 2010) in which several distinct phases in the development can be distinguished:

1) Construction of the theoretical framework: We opted to start from the theoretical framework as proposed by Halpen which is based on a domain-general view of CT. Based on her theoretical framework, Halpern elaborated and validated the Halpern Critical Thinking Assessment (HCTA). In our study the domain-general competencies that are enclosed in the HCTA are translated to domain specific competencies and our test is

developed keeping the construction similar to the HCTA. In principle, this choice allows , comparison of the scores on the domain specific and domain general test in future research.

2) Construction of the test-items: we build on the CTEM-test (Tiruneh, De Cock, Weldeslassie, Elen, & Janssen, 2016), a test developed with the same goal but aiming at higher education (Introductory Physics students). All items of the CTEM-test were reviewed and were adopted to align the physics content and difficulty of the items with formal goals in Flemish secondary education. Where needed, new questions were developed.

3) Through a focus-group discussion with four in service teachers the test-items were discussed. The teachers were asked to indicate whether the item requires CT, whether the question was understandable for the student population, and whether the students should be able to answer the question. Based on this discussion, minor changes were made to some of the items;

4) Cognitive interviews (Willis, 2004) were done with four students of the targeted population. Students were asked to complete the test and to think aloud while doing so. The goal of these cognitive interviews was to figure out whether the students comprehended and respond to the questions the way the researchers intended. Again some, but not all, test items needed minor changes.

5) Large group administration: The final test was administered to 162 students (from 9 different classes in 6 different schools, average age of the participating students was 16.9 ± 0.4 years). The students were given one teaching period (50 minutes) to complete the test. The test was given to the students 3 months after completing the course on electricity and magnetism.

RESULTS

Internal consistency of the test was found to be $\lambda_6 = 0.639$. This value is relatively low, a value of 0.7 is often set as minimum (Sijtsma, 2009). However, for a test that measures complex cognitive abilities, as certainly CT is, a lower internal consistency is not only expected but also wanted (Peters, 2014).

Given the time constraints only two thirds of the students (N=105) were able to complete the entire test. Only tests that were complete were considered in the analyses. On average the students scored 9 ± 4.5 out of a possible 46 points.

DISCUSSION AND CONLUSION

A test that reflects the structure of the Halpern Critical Thinking Assessment was developed to measure to which extent students in secondary education are able to think critically with regard to the subject of electricity and magnetism. The test can be used to advance the discussion on domain specific versus domain general critical thinking and it can be used to quantify the effect of an intervention aiming at enhancing the critical thinking of students.

The average score obtained by the participating students is remarkably low. Even though the sample in this study cannot be said to be representative for all students in Flanders, the results raise a number of questions:

1) Was the test was too difficult for the students? This seems unlikely as all questions were adequately answered by at least some students. Additionally, in stage 3 of the test-development the in-service teachers confirmed that all questions should be feasible for their students.

2) Was the test given to the students at a poorly chosen time? While there might be some merit to this explanation for the low scores, it is quite worrisome. After all, this might imply that the students do not remember the content of the previous year. However, if the CT-skills are specific to the domain of physics

they should still be using these skills at the time the test was taken. The scores show they did not, leading to the following question.

3) Are students not adequately prepared to think critically in their school career? If the answer is "yes" this is quite worrisome as this means that a major educational goal was not reached.

Future research should try to answer the questions asked above, as well try to design an educational methodology to increase the CT skills and disposition among secondary education students. An infusion approach seems promising (Davies, 2006; Tiruneh et al., 2016).

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